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AN ODOR SURVEY OF THE TWO KANSAS CITYS

Earl V. Porter

Public Health Service
Washington, D. C.

July 1965

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AN ODOR SURVEY OF THE TWO KANSAS CITYS

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U.S. Department of Health, Education, and Welfare

A Cooperative Study
by the Cities of Kansas City, Kansas,
and Kansas City, Missouri, and the
Public Health Service
U.S. Department of Health, Education, and Welfare

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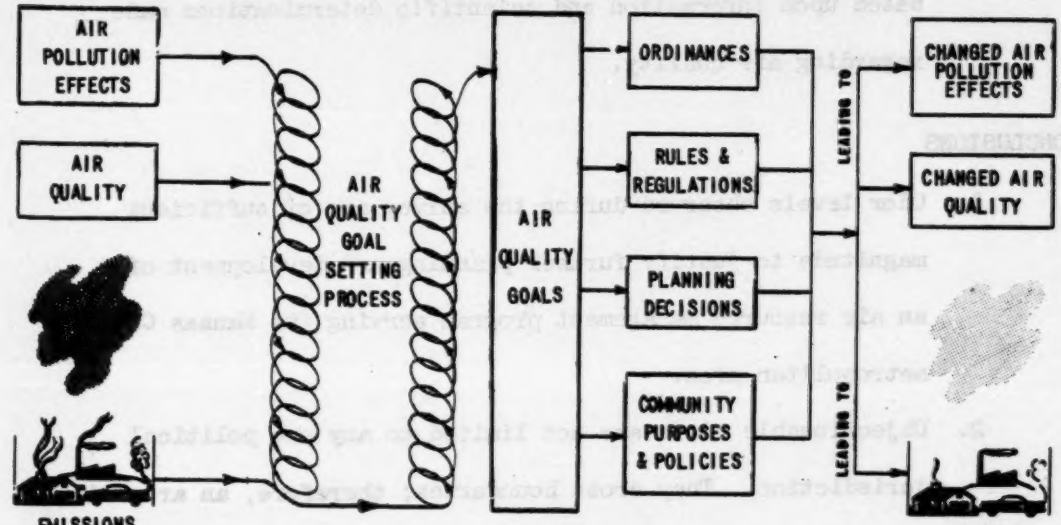
TABLE OF CONTENTS

	Page
CONCLUSIONS AND RECOMMENDATIONS	1
Conclusions	2
Recommendations	4
AN ODOR SURVEY OF THE TWO KANSAS CITYS	6
Purpose and Scope	6
Introduction	7
The Odor Survey	10
Presentation and Analysis of the Survey Data	14
What Are the Kinds of Odors?	14
Where Do Odors Exist?	20
When Are Odors Prevalent?	26
What Are the Intensities of the Odors?	28
What Are the Effects of Meteorological Conditions on Odors?	31
REFERENCES	37
APPENDIX	
Odor Occurrences by Wind Direction (Odor Rose)	A-1
Percentage Frequencies of Wind Direction	A-6
Meteorological Data	A-7
Pasquill-Gifford-Turner Key to Stability Categories	A-9

CONCLUSIONS AND RECOMMENDATIONS

This odor survey report relates to one facet of an air resource management program pertinent to the Kansas City metropolitan area. An air resource management program is a comprehensive and multifaceted approach to the problems of air pollution and the use of the air resources of an air pollution basin.* The following flow diagram indicates its method of operation.



AIR RESOURCE MANAGEMENT FLOW DIAGRAM

The principal air resource management activity areas consist of the following:

1. A continuing air quality monitoring program.
2. A current and continuing air pollutant emission inventory.

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* The term "air pollution basin" refers to an area in which air pollutants originate and collect, and in which the principal effects of those pollutants occur.

3. Air quality goals or standards.

4. A thorough knowledge and use of the conditions influencing the transport of air pollutants.

5. Urban planning decisions based on air quality, as well as other environmental factors.

6. Air pollution control decisions and resulting ordinances based upon information and scientific determinations made regarding air quality.

CONCLUSIONS

1. Odor levels observed during the survey are of sufficient magnitude to justify further planning and development of an air resource management program serving the Kansas City metropolitan area.

2. Objectionable odors are not limited to any one political jurisdiction. They cross boundaries; therefore, an area-wide approach to their study and control is required. This is illustrated by the joint efforts of agencies of the two cities that produced this report.

3. Kansas City, Kansas, and Kansas City, Missouri, experience frequent odors in many areas.

4. Odors are most frequent in the river bottoms of the Kansas and Missouri Rivers where the frequency of occurrence varied

from a high of 86 percent to a low of 50 percent at the nine observation stations.

5. Frequent odors encountered at the stations surrounding downtown Kansas City, Missouri, indicated that the downtown business district itself experiences frequent odors.
6. In the northern suburban area of Kansas City, Missouri, and the higher elevation areas of Kansas City, Kansas, odor frequencies were low, with most odors reported being of the least offensive types.
7. The odors reported most frequently were (a) stockyards district, (b) transportation, (c) smoke.
8. Odors were detected 30.2 percent of all the times observations were made; however, at individual stations, this varied from a low of 2 percent to a high of 86 percent.
9. Variations in the occurrences of odors between different daily observation hours were slight. The highest was 32.5 percent of all observations at 7 a.m., and the lowest was 25.1 percent at midnight. The midnight decrease resulted from a reduction in smoke and transportation odors.
10. The occurrence of odors by wind direction, using the four primary directions, was relatively constant for each direction when the entire survey area was considered as a unit. Individual stations, however, experienced marked variations in odor frequency with wind direction.

RECOMMENDATIONS

1. Start developing a comprehensive air resource management program, utilizing this report to develop further an odor surveillance and control program. This odor control program should consist of at least the following parts:
   A. A 2-week-per-year odor observation program, utilizing firemen and others as odor observers.
   B. A complaint-recording program, coordinated between the various agencies in the area now receiving air pollution complaints. Utilize data-processing methods in recording and analyzing these reports.
   C. Provide for expansion of the program so that it will become an adequate part of the air resource management program. Make a provision in the program to assure prompt reporting and prompt yearly preparation of reports covering the findings of A and B.
2. Define air quality in the Kansas City metropolitan area on a continuing basis. This activity should measure at least the following air pollutants: particulates, sulfur dioxide, oxidants, nitrogen oxides, and ozone.
3. Provide guidelines for the community renewal plan in the following subject areas:
   A. Air quality goals.
   B. Air pollutant emission limitations.
   C. Zoning performance standards.

4. Plan, organize, and develop the necessary organization to institute a regional air resource management program. An initial approach could be the development of a cooperative committee on air pollution. This committee could be called the Kansas City Metropolitan Area Air Resource Management Committee, having as its task the development of an air resource management plan and the coordination of survey and other activities on a cooperative basis until such time as a legally constituted body could be developed. The committee should consider the initiation in other parts of the metropolitan area of survey activities similar to those being undertaken by Wyandotte County in Kansas.

AN ODOR SURVEY OF THE TWO KANSAS CITYS

PURPOSE AND SCOPE

In a letter dated August 29, 1963, from Mr. Carleton F. Sharpe, City Manager of Kansas City, Missouri, to Mr. Vernon G. MacKenzie, Chief, Division of Air Pollution, U.S. Public Health Service, Washington, D.C., a request was made for assistance from the Federal Government in determining the type and general level of odors in the central industrial district of Kansas City, Missouri, and Kansas City, Kansas. The letter reads in part as follows:

> "The Central Industrial District of Kansas City, Missouri, and Kansas City, Kansas, is the 'stock yards' district of this metropolitan area. Some large industrial operations are located partly in Missouri and partly in Kansas. While the district has long been noted for its characteristic odors, this nuisance has been generally accepted as a consequence of the stock yard industry.
>
> ". . . while action to reduce odors is needed now, there is little interest in support of an abatement program. At this time we wish to establish the type and general level of odors now existing.
>
> ". . . we respectfully request assistance from the Public Health Service in conducting such studies and investigations of this problem as may be considered appropriate . . . ."

As a result of City Manager Sharpe's letter, a meeting with representatives of the following agencies was convened at the Kansas City, Missouri, Pollution Control Department on October 8, 1963:

Kansas State Department of Health

Kansas City, Missouri, Health Department

Kansas City, Kansas,-Wyandotte County Health Department

Kansas City, Missouri, Pollution Control Department

U.S. Public Health Service

Representatives of these agencies agreed that an odor survey should be conducted in the two Kansas Citys. It was decided that a survey with special attention given to the central industrial area would be conducted for a 2-week period during the first part of December 1963. The purpose of the study was to determine the type and general level of the odor problem of this area.

INTRODUCTION

The most difficult air pollution problems to define are those involving odors. Webster's Dictionary defines odor as "that property of a substance which affects the sense of smell; any smell; scent; fragrance." Thus odors are tied to a subjective method of measurement, and the problem of defining them precisely is difficult. An odor may be pleasant to one person and offensive to another. In some cases, these odor sensations may be related to psychological factors. Fortunately low concentrations that are very objectionable to the human sense of smell are rarely harmful to health. Unfortunately these low concentrations are almost impossible to measure quantitatively with present measuring methods. For these reasons, a working definition of an offensive odor has been developed that recognizes the role of the human sense of smell. It is: An odor that is objectionable to a majority of healthy persons exposed to its olfactory action.

The knowledge of how human beings react to odors is especially important in a community odor survey because most of such surveys rely mainly on observations taken by "untrained" persons. Basic facts about human olfaction important to odor surveys are:

1. All normal people can smell.

2. People suffering from brain lesions, injured olfactory nerves, or obstructed nasal passages may be unable to smell odors.

3. The ability to sense certain smells but not others does exist.

4. Characteristics of an odor may change on dilution.

5. The sense of smell is rapidly fatigued. Fatigue for one odor may not affect the perception of other dissimilar odors, but will interfere with the perception of similar odors.

Accurate determination of the distribution of odors in an area cannot be fully achieved by the investigation of odor complaints received. By the time an investigator arrives at the scene of the complaint, the odor situation may have changed; therefore, one of the most effective ways to determine the odor problem in a particular area is to conduct a systematic odor survey. This type of survey provides area-wide coverage, establishes what section of the area is most severely affected, and determines how often and when people experience odors. To conduct such a systematic odor survey, many observers are usually used.

The occurrence and intensity of odors at a location are the result of a number of interrelated factors, the most important being the activity levels of affecting odor sources, the area topography, and the meteorological factors of wind direction, wind speed, and atmospheric stability.

The odor emission activity levels of most sources fluctuate throughout the day. During the business hours of the day, odors due to transportation, most industries, and incineration are emitted at their maximum rate. In the evening, home-heating emissions are at their maximum, whereas other emissions decrease.

Meteorological conditions alter the effects of odor emissions. Wind direction determines where odors travel from their sources, whereas wind speed determines their dispersion rate and pattern.

At low wind speeds, odors are more concentrated, but at higher wind speeds the turbulence caused by the wind disperses odors in horizontal and vertical directions. Sometimes wind dispersion reduces odor concentrations below the threshhold limit and, at other times, increases their prevalence by bringing emissions from higher altitude sources down to the ground.

Atmospheric stability also affects the frequency and intensity of odors by altering thermal turbulence. Stable conditions, the opposite of turbulent conditions, exist when the air becomes progressively cooler and, therefore, more dense nearer the earth's surface. During the day, when the earth's surface is heated by the sun's radiation, the air adjacent to it is also heated and becomes less dense per unit volume than the air above it. The less dense air rises and produces thermal turbulence of the atmosphere.

On clear nights with light winds, heat radiated from the earth's surface cools the ground and the air adjacent to it. This action produces extreme stability of the atmosphere near the earth's surface and a minimum of turbulence or mixing. The presence of cooler air near the ground surface with a layer of warmer air above is called an inversion, air temperatures inverted from normal. The term "nocturnal inversion" is used to describe the inversions that frequently develop at night for the reasons described above.

The effect of topography on the occurrences of odors is due to the changes in wind direction, wind speed, airflow, and stability conditions that the local topography produces. A physical feature such as a low valley flanked by hills experiences frequent stability conditions in which air pollutant emissions can build up in the air.

Hillside or hilltop areas are often directly in the path of emissions from smokestacks and chimneys in neighboring valleys and are, therefore, more susceptible to odors and smoke from these sources. These alterations of local meteorological conditions by area topography limit the application of meteorological data obtained at not-too-distant observation stations; this adds to the difficulty of determining the location of the sources of odors observed.

THE ODOR SURVEY

The odor survey was conducted in the two Kansas Citys for a 2-week period from December 9 through December 22, 1963.

The cooperation of the Kansas City, Missouri, and Kansas City, Kansas, fire departments was obtained by the cities' health agencies.

The selection of the firemen as observers resulted from their willingness and 24-hour availability. Selection of observation points was made by the health departments. Eleven fire stations were selected on the Kansas side, and 16 were selected in Missouri. Figure 1 is a map of the survey area, showing the locations of the observation stations.

The general topography of the survey area is indicated by Figure 2.

Observations were taken at 7:00 a.m., 2:00 p.m., 8:00 p.m., 10:00 p.m., and 12:00 midnight. Observers were instructed to go outside the firehouse; take a few quick, deep sniffs of the air; and then record in their own words what was smelled. Forms for recording the information were provided.

All observers were given an odor sensitivity test, the primary purpose of which was to make sure that the men were capable of detecting odors. The test also gave the observer a relative feeling of what was considered a strong or faint odor and gave the tester a chance to indoctrinate and motivate the observers. The chemicals used for the odor test were vanillin, amyl acetate, and butyric acid (see Table 1). The first two odorants are pleasant, whereas the third, butyric acid, has a stench much like rancid butter. Three dilutions were prepared for each odorant, one considered to be below the normal threshhold or detectable level, one detectable by a majority of the normal population, and one which was a factor of 10 higher than the normal detectable level. The observer was asked to select the container with the odor from a group of three, two of which were distilled water. Nine separate selections were made by each observer.

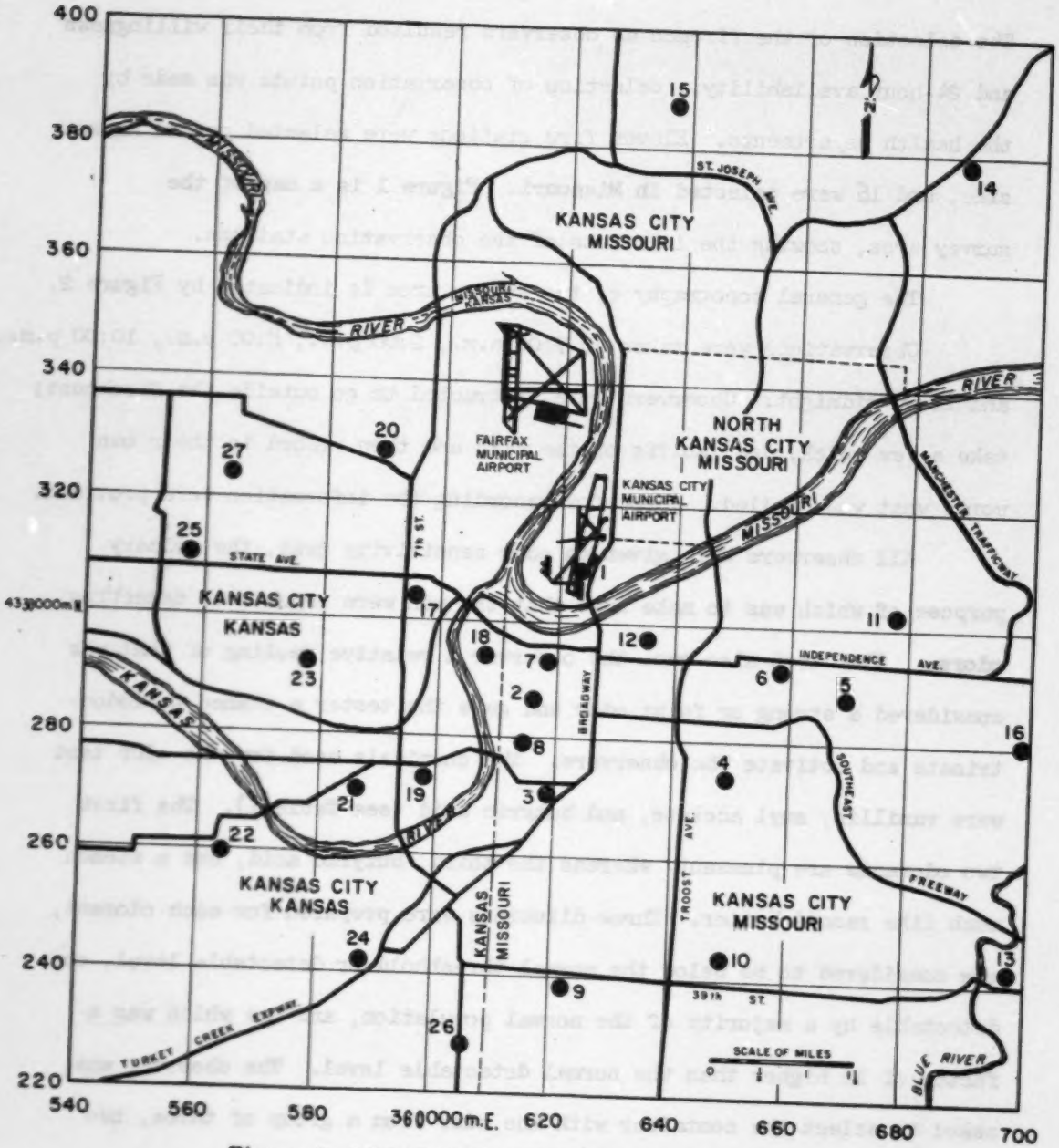

Figure I. LOCATIONS OF OBSERVATION STATIONS

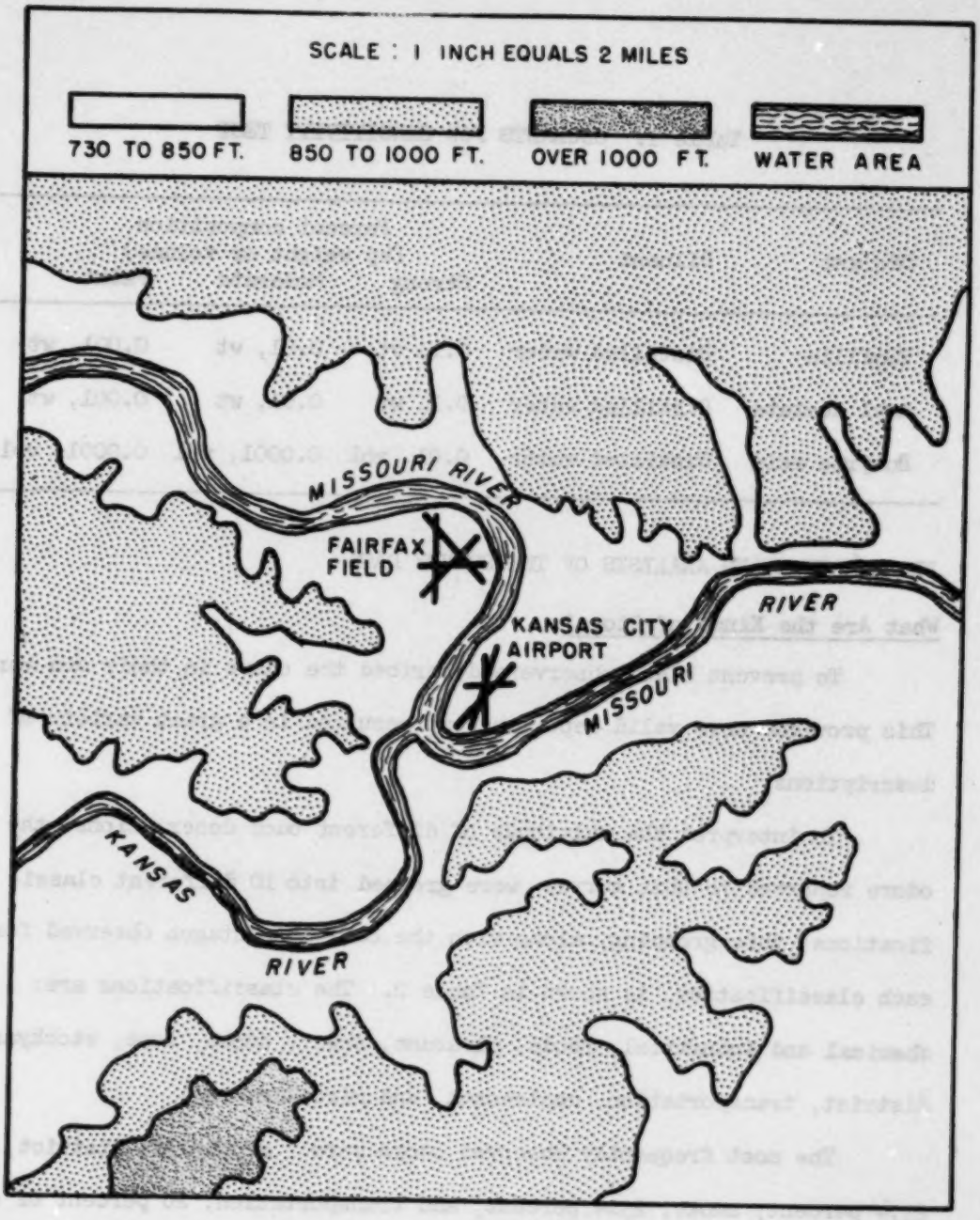

Figure 2. LOCAL TOPOGRAPHY—KANSAS CITY, KANSAS & KANSAS CITY, MISSOURI
(U.S. WEATHER BUREAU)

Table 1. ODORANTS FOR SENSITIVITY TEST

Odorant	Diluent	Percent composition (by weight or volume) Strong	Moderate	Faint
Vanillin	Distilled water	0.1, wt	0.01, wt	0.001, wt
Amyl acetate	Distilled water	0.1, wt	0.01, wt	0.001, wt
Butyric acid	Distilled water	0.01, vol	0.0001, vol	0.0001, vol

PRESENTATION AND ANALYSIS OF THE SURVEY DATA

What Are the Kinds of Odors?

To prevent bias, observers described the odors in their own words. This provided more valid reporting but resulted in a great variety of descriptions.

To interpret the multitude of different odor descriptions, the odors reported in this survey were grouped into 10 different classifications; this grouping, along with the odor percentages observed for each classification, is shown in Table 2. The classifications are: chemical and industrial, foods, pleasant, sewer, smoke, soap, stockyards district, transportation, unpleasant, and miscellaneous.

The most frequently observed odors were: stockyards district, 23.4 percent; smoke, 23.4 percent; and transportation, 20 percent of all odors observed. These three types of odors were the most numerous for the entire survey area; however, other odors were more prevalent at certain individual observation stations.

Table 2. SUMMARY OF TYPES OF ODORS OBSERVED

Odor classification	Description	Number of observations	Percentage of odors observed
Chemical and industrial		Total - 32	5.7
	Asphalt	1	
	Chemical	11	
	Chemical laboratory	1	
	Chlorine	1	
	Paint	2	
	Rubber	1	
	Sulfur	15	
Foods		Total - 13	2.3
	Bakery	9	
	Food cooking	1	
	Ham smoking	1	
	Meat burned	1	
	Roast beef	1	
Pleasant		Total - 46	8.2
	Clear	6	
	Fresh air	37	
	Sweet	2	
	Vanilla	1	
Sewer		Total - 16	2.9
	Rotten eggs	1	
	Sewer	11	
	Sewer gas	4	
Smoke		Total - 131	23.4
	Burned wood	15	
	Chimney	36	
	Coal	5	
	Coal gas	2	
	Dump fire	1	
	Smoke	52	
	Trash wood smoke	20	
Soap		Total - 42	7.5
	Fish	7	
	Soap	35	

Table 2. SUMMARY OF TYPES OF ODORS OBSERVED (CON'TD)

Odor classification	Description	Number of observations	Percentage of odors observed
Stockyards district		Total - 131	23.4
	Fertilizer	14	
	Manure	6	
	Packing house	42	
	Pig pen	1	
	Rendering	14	
	Stockyards	54	
Transportation		Total - 112	20.0
	Carbon fumes from autos	5	
	Brake and clutch	2	
	Diesel	29	
	Exhaust	6	
	Kerosene	25	
	Motor fuel	4	
	Oily	23	
	Petroleum	18	
Unpleasant		Total - 14	2.5
	Bad	1	
	Damp	5	
	Foul stench	2	
	Toxic	1	
	Unpleasant	4	
	Wet newspaper	1	
Miscellaneous		Total - 23	4.1
	Dust	1	
	Faint	1	
	Feed	7	
	Gas	1	
	Hot metal	3	
	Rotten vegetables	1	
	Skunk	1	
	Soybean	1	
	Stale garbage	1	
	Steam laundry	1	
	Tar	2	
	Unknown	3	
Totals		560	100.0

The stockyards district odor was reported most frequently, in the words of the observers,* as "stockyards" or "packing house," followed by use of the terms "rendering plant" and "fertilizer"; all are associated with the stockyard - meat-packing industries. This class of odors was very prevalent in the river bottom industrial area along the Kansas River at stations 2, 7, 8, 18. and 19.

Figure 3 indicates the area where stockyards district odors were observed. It shows that, although they are concentrated principally in the river bottom area, these odors do, at times, affect a wide area. Station 24, located 3½ miles south of the stockyard area, experienced the stockyards district class of odors on two occasions, both times with the wind coming from the direction of the stockyard district. Frequent stockyards district odors were also observed at station 12, located on the heights overlooking the Missouri River near downtown Kansas City, Missouri.

Transportation odors, which are due to air, rail, and automobile travel, were reported from many observation stations. In the observers own words, these odors were usually reported as "diesel," "kerosene," "oily," and "petroleum." These odors occurred principally in the industrial river bottom area along the Kansas River and at the Kansas City Municipal Airport station, which reported the highest incidence of these odors. Figure 4 indicates the areas where transportation odors frequently occur.

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* In this report, odor types are set off in quotation marks when they represent descriptions in the words of the observers.

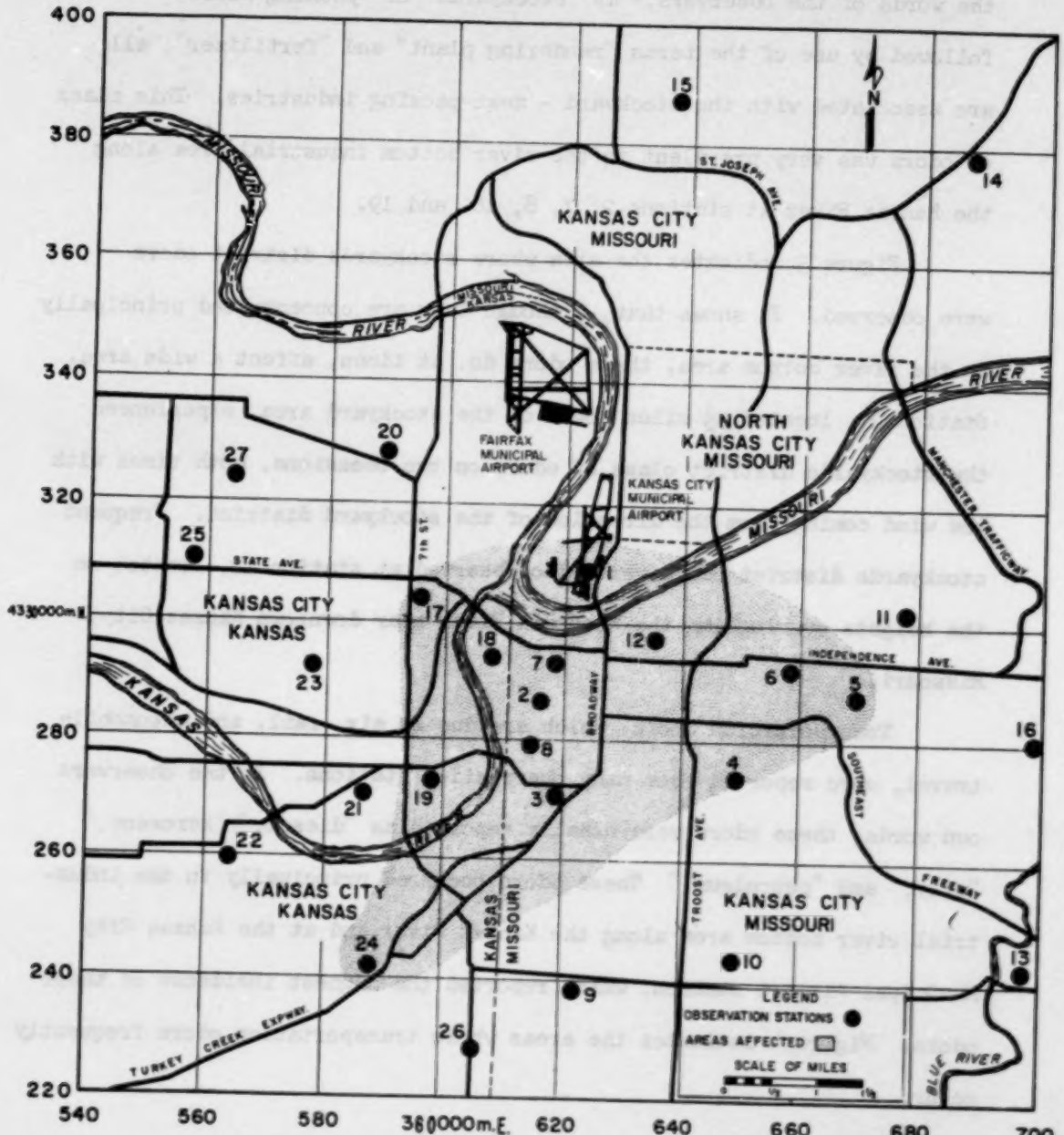


Figure 3. AREAS AFFECTED BY STOCKYARDS DISTRICT ODORS

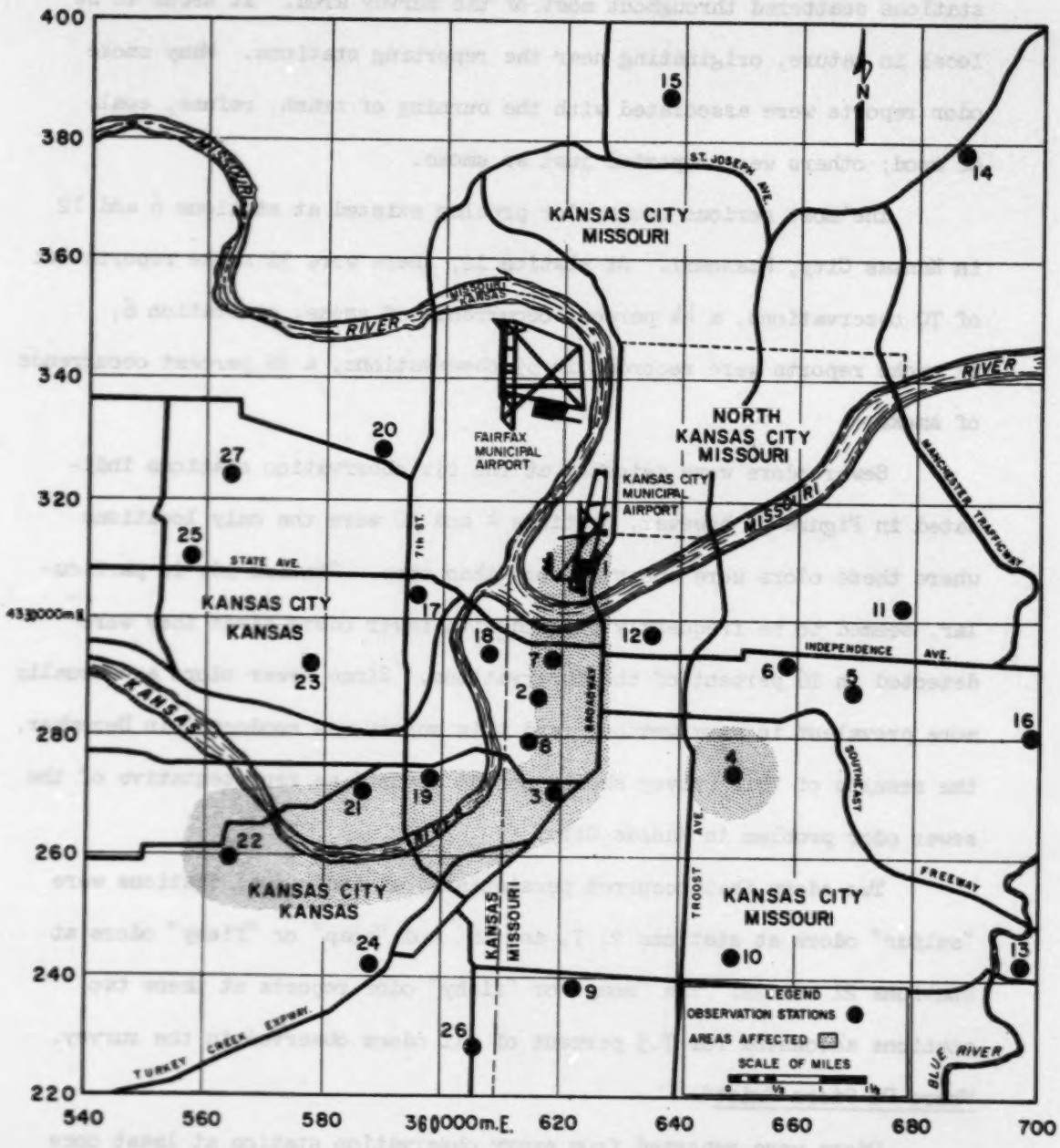


Figure 4. AREAS AFFECTED BY TRANSPORTATION ODORS

The odor of smoke was also reported from a large number of stations scattered throughout most of the survey area. It seems to be local in nature, originating near the reporting stations. Many smoke odor reports were associated with the burning of trash, refuse, coal, or wood; others were reported just as smoke.

The most serious smoke odor problem existed at stations 6 and 12 in Kansas City, Missouri. At station 12, there were 31 smoke reports out of 70 observations, a 44 percent occurrence of smoke; at station 6, 13 smoke reports were recorded in 59 observations, a 22 percent occurrence of smoke.

Sewer odors were detected at the six observation stations indicated in Figure 5; however, stations 4 and 10 were the only locations where these odors were observed more than once. Station 10, in particular, seemed to be frequently plagued with sewer odors since they were detected in 16 percent of the observations. Since sewer odors are usually more prevalent in warm weather and this survey was conducted in December, the results of this survey should not be assumed as representative of the sewer odor problem in Kansas City.

Two odors that occurred persistantly at individual stations were "sulfur" odors at stations 2, 7, and 16, and "soap" or "fishy" odors at stations 21 and 22. The "soap" or "fishy" odor reports at these two stations accounted for 7.5 percent of all odors observed in the survey.

Where Do Odors Exist?

Odors were reported from every observation station at least once during the 2-week survey period; therefore, there is no one area

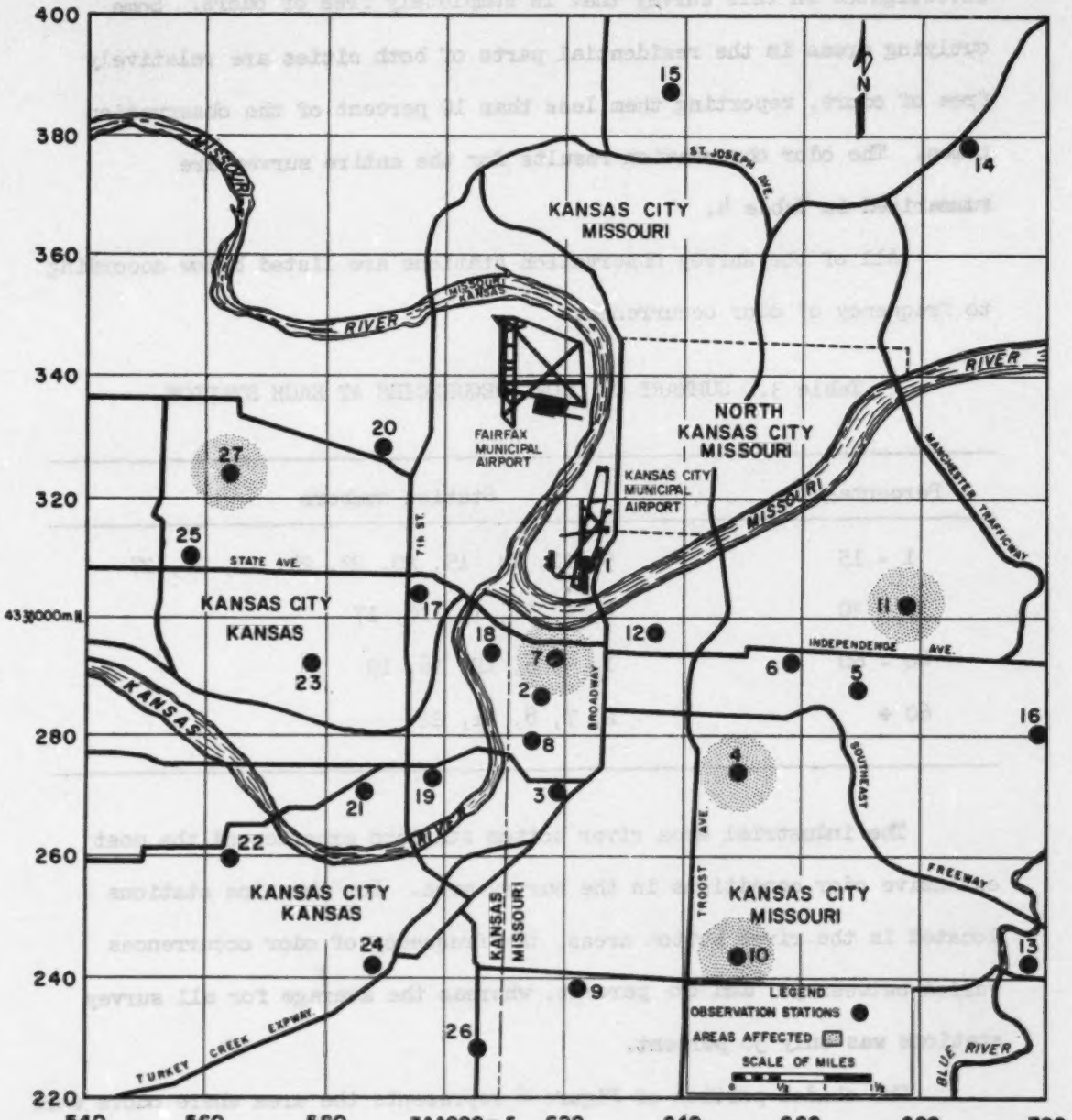


Figure 5. AREAS AFFECTED BY SEWER ODORS

investigated in this survey that is completely free of odors. Some outlying areas in the residential parts of both cities are relatively free of odors, reporting them less than 10 percent of the observation times. The odor observation results for the entire survey are summarized in Table 4.

All of the survey observation stations are listed below according to frequency of odor occurrences.

Table 3. SUMMARY OF ODOR FREQUENCIES AT EACH STATION

Percentage	Station numbers
1 - 15	5, 11, 14, 15, 20, 23, 24, 25, 26, 27
16 - 30	4, 9, 10, 13, 16, 17
40 - 60	1, 3, 6, 12, 18, 19
60 +	2, 7, 8, 21, 22

The industrial area river bottom stations experienced the most extensive odor conditions in the survey area. For the nine stations located in the river bottom areas, the frequency of odor occurrences varied between 50 and 86 percent, whereas the average for all survey stations was only 30 percent.

The shaded portion of Figure 6 represents the area where odors were most frequently present (greater than 44 percent of the time). In addition to the river bottom areas, it encompasses much of the central part of Kansas City, Missouri, including the downtown business district. The odors

Table 4. SUMMARY OF ODORS OBSERVED AT EACH STATION AND AT DIFFERENT HOURS OF THE DAY

Station number	No. of odors observed — Observation time 0700	1400	2000	2200	2400	Total number of odors observed	Total number of observations	Percentage of time odors were observed at each station
1	5	10	8	9	3	35	70	50
2	8	10	7	6	6	37	70	53
3	8	4	5	8	6	31	70	44
4	1	4	2	3	2	12	66	18
5	0	0	2	0	0	2	68	3
6	10	3	4	8	6	31	59	53
7	10	8	9	8	7	42	65	65
8	6	6	6	6	6	30	35	86
9	4	1	2	3	1	11	39	28
10	4	5	2	2	3	16	68	24
11	1	0	2	2	0	5	58	9
12	9	5	5	8	8	35	70	50
13	5	3	6	2	2	18	70	26
14	0	1	0	0	0	1	68	2
15	3	0	4	2	1	10	68	15

Table 4. SUMMARY OF ODORS OBSERVED AT EACH STATION AND AT DIFFERENT HOURS OF THE DAY (CONT'D)

Station number	No. of odors observed — Observation time 0700	1400	2000	2200	2400	Total number of odors observed	Total number of observations	Percentage of time odors were observed at each station
16	2	2	1	1	1	7	30	23
17	1	0	7	3	1	12	70	17
18	7	8	10	7	5	37	70	53
19	4	4	6	6	5	25	44	54
20	1	0	0	0	1	2	58	3
21	11	11	9	10	8	49	67	73
22	5	7	9	12	11	44	70	63
23	0	1	0	0	0	1	68	2
24	1	0	0	0	1	2	70	3
25	2	3	1	0	1	7	70	10
26	1	2	1	0	0	4	70	6
27	2	2	1	3	0	8	70	11
Totals	111	100	104	109	85	514	1,701	30.2
Total No. of observations	342	342	343	340	334			
% of times odors were observed at different hours of the day	32.5	29.2	31.8	32.1	25.1			

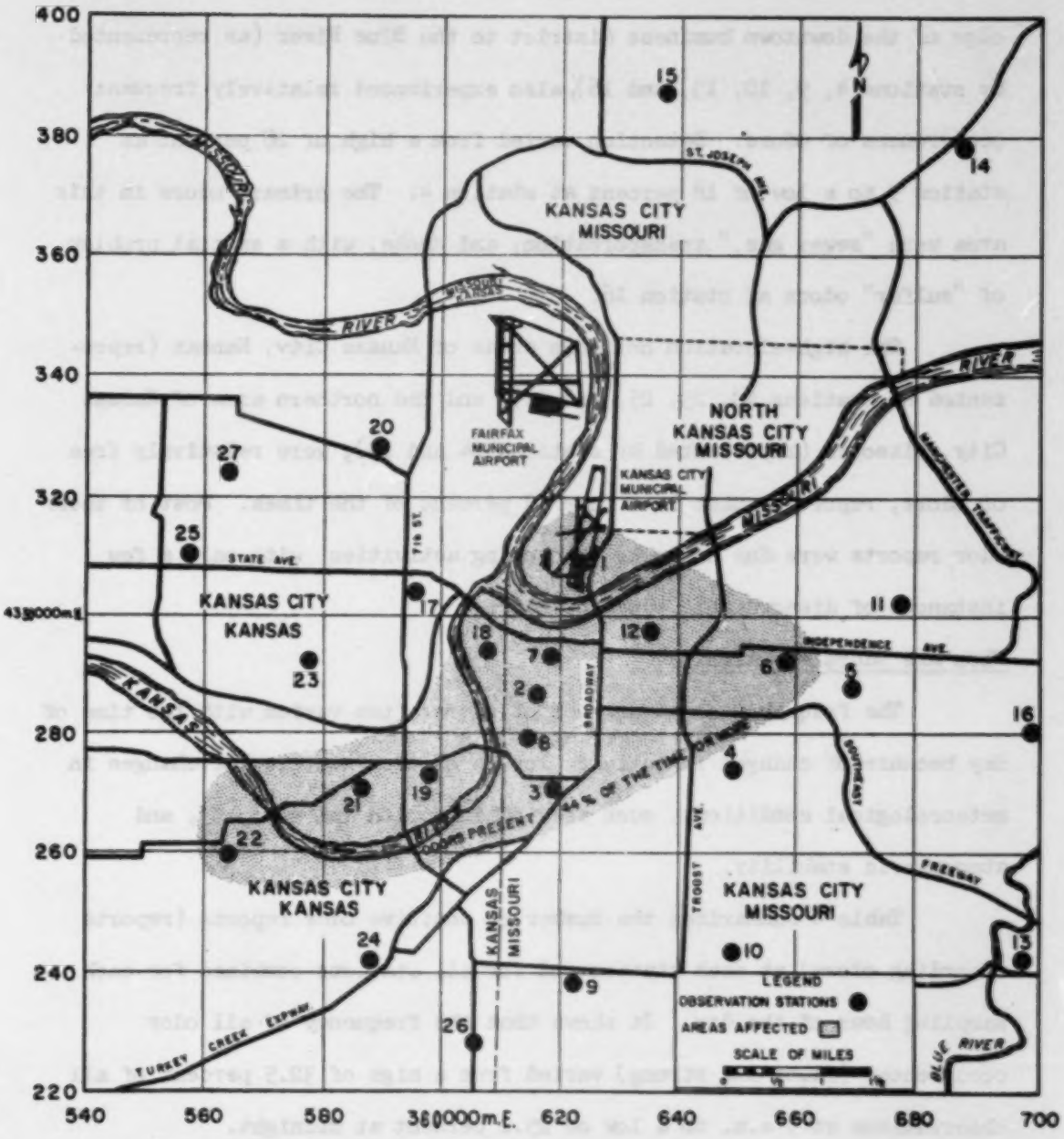


Figure 6. AREAS AFFECTED BY FREQUENT ODORS OF ALL TYPES

most often experienced in this area are the stockyards district, transportation, smoke, and chemical and industrial types.

The area of Kansas City, Missouri, extending southeast from the edge of the downtown business district to the Blue River (as represented by stations 4, 9, 10, 13, and 16), also experienced relatively frequent occurrences of odors. Detection varied from a high of 28 percent at station 9 to a low of 18 percent at station 4. The primary odors in this area were "sewer gas," transportation, and smoke, with a special problem of "sulfur" odors at station 16.

The high-elevation northern areas of Kansas City, Kansas (represented by stations 20, 23, 25, and 27), and the northern area of Kansas City, Missouri (represented by stations 14 and 15), were relatively free of odors, reporting them less than 15 percent of the times. Most of these odor reports were due to smoke or cooking activities, with only a few instances of disagreeable types of odors.

When Are Odors Prevalent?

The frequency of occurrence of odors often varies with the time of day because of changes in activity levels of odor sources and changes in meteorological conditions, such as wind direction and velocity, and atmospheric stability.

Table 4 summarizes the number of positive odor reports (reports recording odors) at each station and for all stations combined for each sampling hour of the day. It shows that the frequency of all odor occurrences (faint and strong) varied from a high of 32.5 percent of all observations at 7 a.m. to a low of 25.1 percent at midnight.

The frequency of occurrences of the three primary types of odors (stockyards district, transportation, and smoke) for different hours of the day are presented in Table 5. This table indicates that stockyards

Table 5. TYPES OF ODORS OBSERVED AT DIFFERENT TIMES OF THE DAY

Observ. time		Odor Type			
		Stock-yards district	Transpor-tation	Smoke	All odors
0700	No. of odor reports	22	28	23	111
	% of all odors	20	25	21	-
	% of observations	6.5	8.2	6.7	32.5
1400	No. of odor reports	19	24	23	100
	% of all odors	19	24	23	-
	% of observations	5.5	7.0	6.7	29.2
2000	No. of odor reports	23	24	28	104
	% of all odors	22	23	27	-
	% of observations	6.7	7.0	8.2	31.8
2200	No. of odor reports	21	30	31	109
	% of all odors	19	28	28	-
	% of observations	6.2	9.1	9.1	32.1
2400	No. of odor reports	21	18	18	85
	% of all odors	25	21	21	-
	% of observations	6.3	5.4	5.4	25.1

district odors are constant throughout the day, whereas transportation odors and smoke odors are most numerous at 10 p.m. and least active at midnight. The lowest percentage occurrence of all odors at midnight is due to the drop in smoke and transportation odors.

What Are the Intensities of the Odors?

Table 6 presents a summary of the odor intensity observations at each station and for all stations combined. It shows that for the entire survey, 30 percent of all odors observed were classified as "strong" by the observers. The diurnal variation of the frequency of strong odor occurrences was slight, ranging from a high of 32 percent at midnight and 7 a.m. to a low of 25 percent at 10 p.m.

The times of occurrence of the highest frequency of strong odors are in concert with the times of day of the most stable atmospheric conditions. Although stable conditions begin to develop just after sundown, in a large metropolitan area such as Kansas City with it's many and closely spaced heat sources (the heat island effect), complete stability does not develop until much later at night.

For each station, individually, the frequency of occurrence of strong odors varied considerably. High frequencies of strong odors were obtained at station 2 where 59 percent of all odors were reported as "strong" and at station 22 where 57 percent were reported as such. At station 2, stockyards district and "sulfur" odors accounted for most of the strong odors, whereas at station 22, "diesel fumes" and "wood smoke" were the primary odors.

Approximately one-third of all strong odors were of the stockyards district type with transportation, smoke, "chemical," "soap," "sulfur," and sewer odors, in that order, accounting for virtually all of the remainder.

Table 6. ODOR INTENSITIES

Observation station	Observation time 0700 F	0700 S	1400 F	1400 S	2000 F	2000 S	2200 F	2200 S	2400 F	2400 S	Totals F	Totals S	% Strong
1	3	2	7	3	4	4	8	1	2	1	24	11	31.4
2	1	6	4	5	4	3	1	3	3	2	13	19	59.4
3	3	1	4	0	3	0	7	1	5	1	22	3	12.0
4	4	0	4	1	4	2	4	0	4	0	20	3	13.0
5	0	0	0	0	2	0	0	0	0	0	2	0	0
6	4	5	3	0	2	0	4	0	2	1	15	6	28.6
7	4	5	3	5	8	1	6	2	4	3	25	16	39.0
8	4	2	4	2	5	2	3	2	3	2	19	10	24.4
9	4	0	0	1	2	0	2	0	1	0	9	1	10.0
10	5	0	5	1	2	0	3	0	3	0	18	1	5.7
11	1	0	0	0	2	0	2	0	0	0	5	0	0
12	7	2	4	1	2	3	8	0	6	2	27	8	22.9
13	4	1	3	0	4	1	2	0	2	0	15	2	11.8
14	0	0	1	0	0	0	0	0	0	0	1	0	0
15	3	0	0	0	2	2	1	1	0	1	6	4	40.0
16	2	0	1	1	0	1	0	1	0	1	3	4	57.1
17	0	1	0	0	5	2	3	0	1	0	9	3	25.0
18	4	3	6	2	6	3	5	2	4	1	25	11	30.6
19	4	0	3	1	5	1	5	1	4	1	21	4	16.0
20	0	1	0	0	0	0	0	0	1	0	1	1	50.0
21	7	4	6	4	7	1	5	4	4	3	29	16	35.5

Table 6. ODOR INTENSITIES (CONT'D)

Observation stations	Observation time 0700 F	0700 S	1400 F	1400 S	2000 F	2000 S	2200 F	2200 S	2400 F	2400 S	Totals F	Totals S	% Strong
22	4	1	5	2	2	7	4	8	4	7	19	25	56.8
23	0	0	1	0	0	0	0	0	0	0	1	0	0
24	0	1	0	0	0	0	0	0	1	0	1	1	50.0
25	2	0	2	1	1	0	0	0	1	0	6	1	14.3
26	1	0	1	1	1	0	0	0	0	0	3	1	25.0
27	2	0	2	0	2	0	3	0	0	0	9	0	0
Totals	73	35	69	31	75	33	76	26	55	26	348	151	30.3
% Strong	32		31		31		25		32		30		

F = Faint odor

S = Strong odor

What Are the Effects of Meteorological Conditions on Odors?

The meteorological data for the Kansas City Municipal Airport for the survey period are presented in the appendix. Also included (see Figure A-6) are radial wind direction diagrams (wind roses), showing the occurrence of wind by direction for the survey period at Kansas City Municipal Airport and the percentage frequencies of wind direction for the 10-year (1951-1960) annual average and December average.

A comparison of these diagrams shows that during the survey period a north and north-northeast wind occurred much more frequently than usual, whereas a wind directly opposite, from the south and south-southwest, occurred much less frequently than usual.

A comparison of the wind data for Kansas City Municipal Airport with that for Olathe Naval Air Station showed excellent agreement, which indicates that probably very little, if any, channeling occurs in the Kansas City river bottom area. **The wind data for Kansas City Municipal Airport, therefore, appears to be applicable to the entire survey area.**

Table 8 correlates the distribution of positive odor reports at each station, with each of the 16 wind directions; Table 7 below summarizes these results into four principal wind directions - north, east, south, and west.

Table 7. SUMMARY OF ODOR OCCURRENCES BY WIND DIRECTION

Direction	No. odors	No. observations	% odors
N (NNW, N, NNE, NE)	233	802	29
E (ENE, E, ESE, SE)	42	137	31
S (SSE, S, SSW, SW)	71	217	33
W (WSW, W, WNW, NW)	159	545	29

Table 8. ODORS OBSERVED RELATED TO WIND DIRECTIONS

	Station numbers																											Total Odors observed	Total observations	% of times
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27			
N	6	4	6	1	0	6	5	5	1	4	0	5	3	0	0	0	2	11	5	0	10	12	0	1	0	0	2	90	310	29.0
NNE	5	7	10	2	1	9	4	8	5	1	0	9	6	0	3	4	1	12	10	1	12	11	0	1	1	0	0	123	438	28.1
NE	2	2	1	0	0	0	1	2	0	1	0	0	0	1	1	1	0	2	2	0	1	1	0	0	1	1	0	20	54	37.0
ENE	1	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	8	23	34.8
E	3	2	2	0	0	1	2	0	0	1	0	3	0	0	0	0	2	2	1	0	3	1	0	0	0	0	0	23	68	30.9
ESE	2	2	0	0	0	1	2	0	0	1	1	2	0	0	1	0	2	1	0	0	2	2	0	0	0	1	1	21	46	45.7
SE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SSE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SSW	1	1	0	0	0	0	2	0	0	1	0	2	1	0	0	0	0	0	0	0	1	1	0	0	1	0	0	11	46	23.9
SW	7	2	4	4	0	4	6	0	2	3	1	3	1	0	0	1	2	4	3	0	6	6	0	0	0	0	1	60	171	35.1
WSW	1	3	2	1	0	3	4	4	1	1	2	4	3	0	2	1	0	0	2	0	4	3	0	0	1	1	1	44	129	34.1
W	1	2	2	1	0	0	2	1	0	0	0	1	0	0	0	0	0	0	0	1	0	2	0	0	1	0	0	14	45	31.1
WNW	3	5	0	2	1	4	8	7	0	0	0	2	2	0	0	0	1	3	1	0	4	2	1	0	1	0	1	48	201	23.9
NW	3	7	3	1	0	2	6	3	2	3	1	3	2	0	2	0	1	1	1	0	6	3	0	0	1	1	1	53	170	31.2
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	35	37	31	12	2	31	42	30	11	16	5	35	18	1	10	7	12	37	25	2	49	44	1	2	7	4	8	514		
No. of obser.	70	70	70	66	68	59	65	35	39	68	58	70	70	68	68	30	70	70	44	58	67	70	68	70	70	70	70		1,701	
% of times	50	53	44	18	3	53	65	86	28	24	9	50	26	2	15	23	17	53	54	3	73	63	2	3	10	6	11			30.2

The variation in odor frequencies with respect to the four primary wind directions is negligible; however, this does not necessarily indicate that both cities will not experience more odors with the wind from certain directions because the observation stations were not selected to give valid geographical area averages.

Wind directions versus odor incidence relationships are most significant for individual local areas. To indicate these relationships for the various parts of the survey area odor occurrences by wind direction radial diagrams (odor roses) were plotted for most of the observation stations. These odor roses are presented in the appendix, Figures A-1 through A-5. Diagrams were not prepared for observation stations that experienced odors of insignificant frequency or type.

At individual stations there were certain wind directions for which odor occurrences and types were more prevalent than when the wind was from other directions. The diagram for station 2 shows that when the wind was from the northwest the incidence of odors in terms of number-percent was greater than when the wind was from the other directions. Similarly at station 7 when the wind was from the southwest or any other direction clockwise through northwest, odors were much more prevalent than when the wind was from the north or north-northeast. Also at this station, stockyards district odors dominated when the wind was from the southwest through the northwest, whereas when the wind was from the north or north-northeast, transportation odors were prevalent.

Odor occurrences by wind direction diagrams are also often used to locate sources of specific odors. These diagrams are especially applicable in relatively flat areas where there are no prominant topographic

obstructions to alter wind directions and channel airflow. An examination of the odor roses at stations 1, 2, 7, 8, 17, and 19 for stockyards district odors (see Figure 7) indicates that their primary source is located within the indicated area on the map.

The meteorological data in the appendix also includes the Pasquill-Gifford-Turner stability index for each observation hour. In this system, a six-letter (A to F) classification is used (see key to stability categories on page A-9 in the appendix). "A" denotes the most unstable condition, and "F" indicates the most stable condition. The classification letter is determined by wind speed and the degree of solar insolation during the daytime (radiation received from the sun) and amount of cloud cover at night.

The percentage occurrence of odors with each stability condition is listed in Table 9 below.

Table 9. OCCURRENCE OF ODORS BY STABILITY CLASSIFICATION

Stability index letter	% odors	No. odors	No observations
C	26	25	97
D	30	275	916
E	33	164	500
F	30	40	136

Note: A and B stability did not exist during the survey.

It is apparent that there is insignificant variation in odor occurrences with respect to stability index letter. This unexpected condition may be due to the arbitrary nature of the stability class system. Also, actual meteorological conditions at individual locations may be quite different because of topographical relief and the heat island effect characteristic of the metropolitan area.

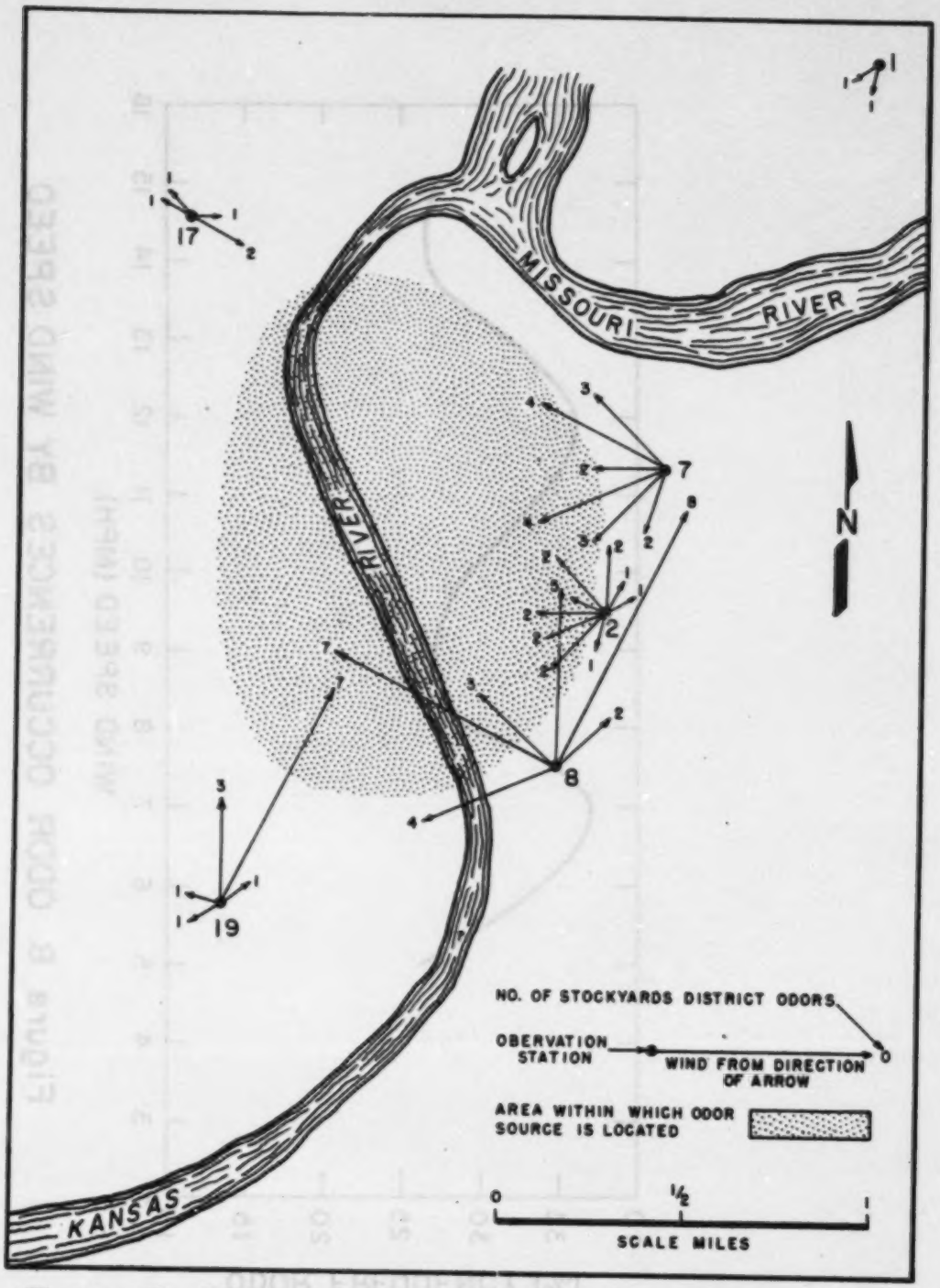


Figure 7. STOCKYARDS DISTRICT ODORS BY WIND DIRECTION AT CERTAIN STATIONS

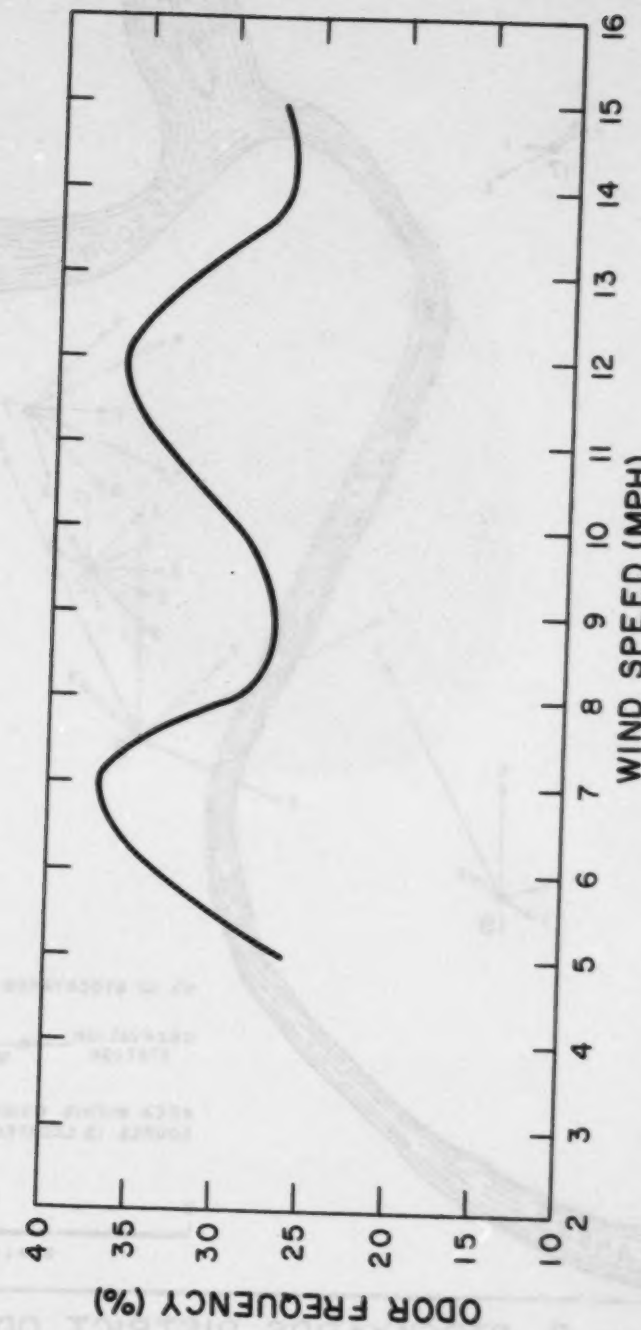


Figure 8. ODOR OCCURRENCES BY WIND SPEED

Attempts to correlate wind speed with odor occurrences also produced unusual results as evidenced by the graph of frequency of odor occurrences versus wind speed (see Figure 8). Normally, odor frequencies would be expected to decrease with increasing wind speed, but peaks were obtained at 7 mph and 12 mph for the data obtained in this survey.

REFERENCES

1. Letter from Mr. Carleton F. Sharpe, City Manager of Kansas City, Missouri, to Mr. Vernon G. MacKenzie, Chief, Division of Air Pollution, U.S. Public Health Service, Washington, D.C.

2. Horstman, S. W., Wromble, R. F., and Heller, A. N., "Identification of Community Odor Problems Using An Observer Corps." A report prepared by the Technical Assistance Branch of the Division of Air Pollution for presentation at the 56th Annual Meeting of the A.P.C.A., Sheraton-Cadillac Hotel, Detroit, Michigan, June 9 to 13, 1963.

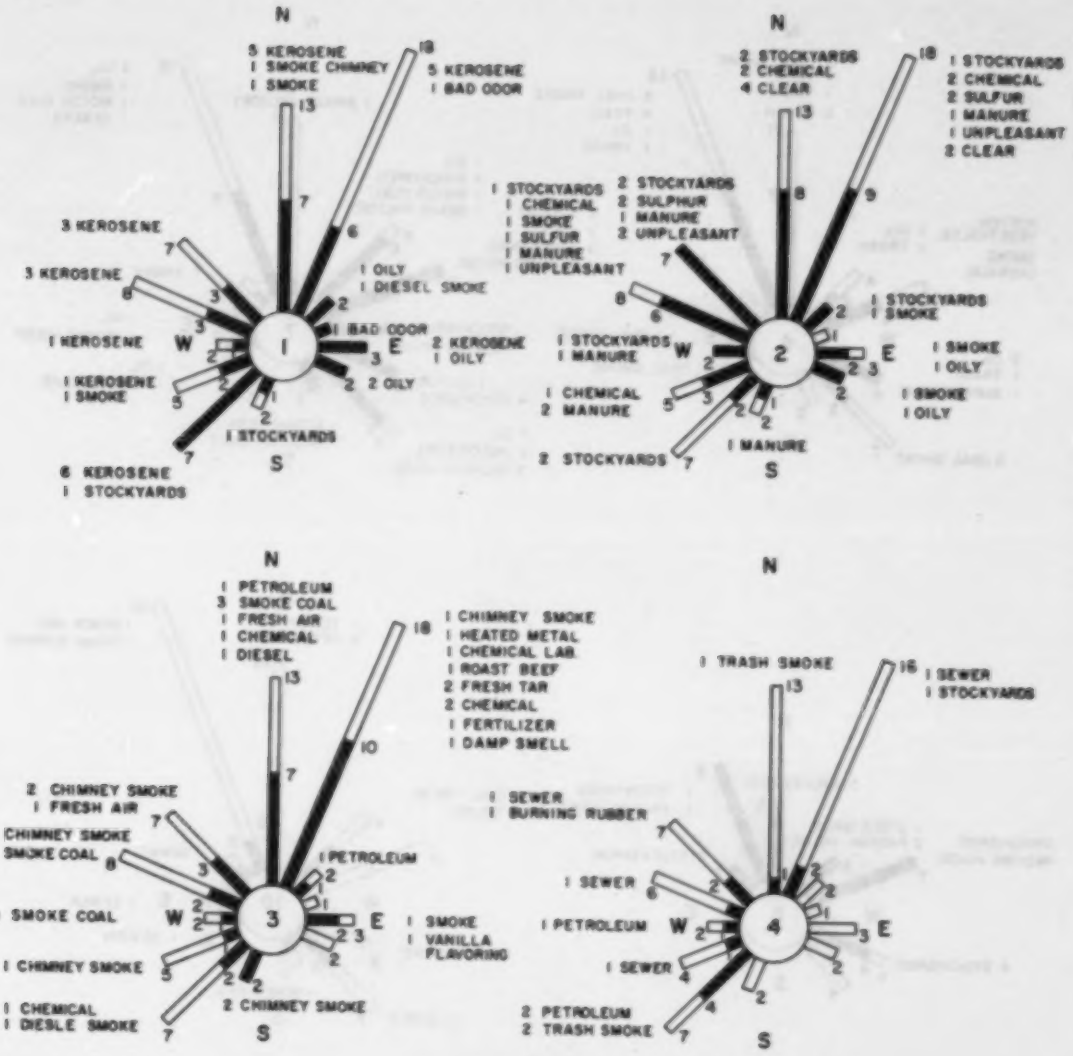
3. Jenkins, H. N., "St. Louis Phase I Odor Report," Unpublished draft document. Interstate Air Pollution Study - St. Louis-East St. Louis Metropolitan Areas. St. Louis, Missouri, September 1963.

APPENDIX

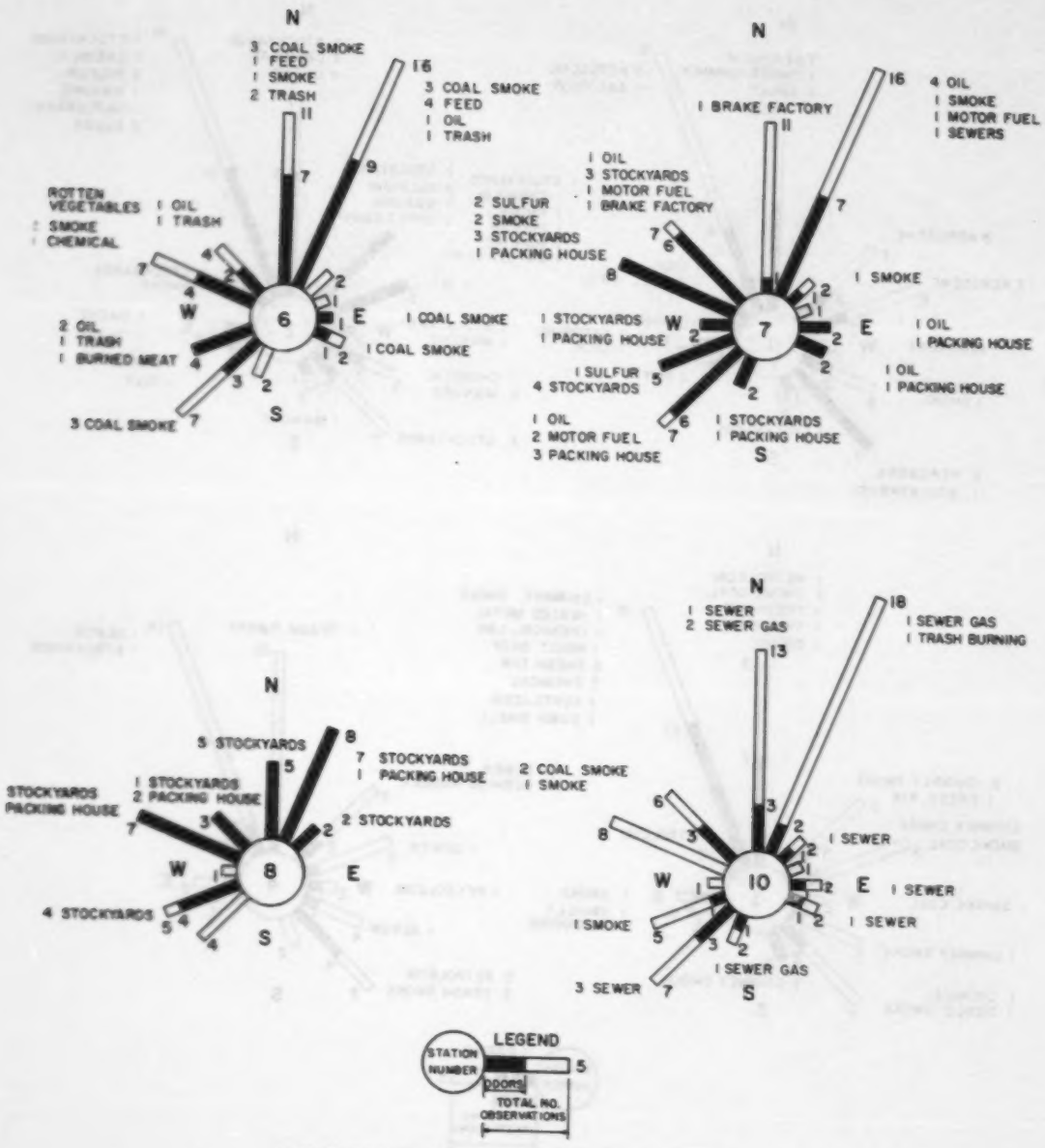
ODOR OCCURRENCES BY WIND DIRECTION

AND

METEOROLOGICAL DATA



ODOR OCCURRENCES BY WIND DIRECTION



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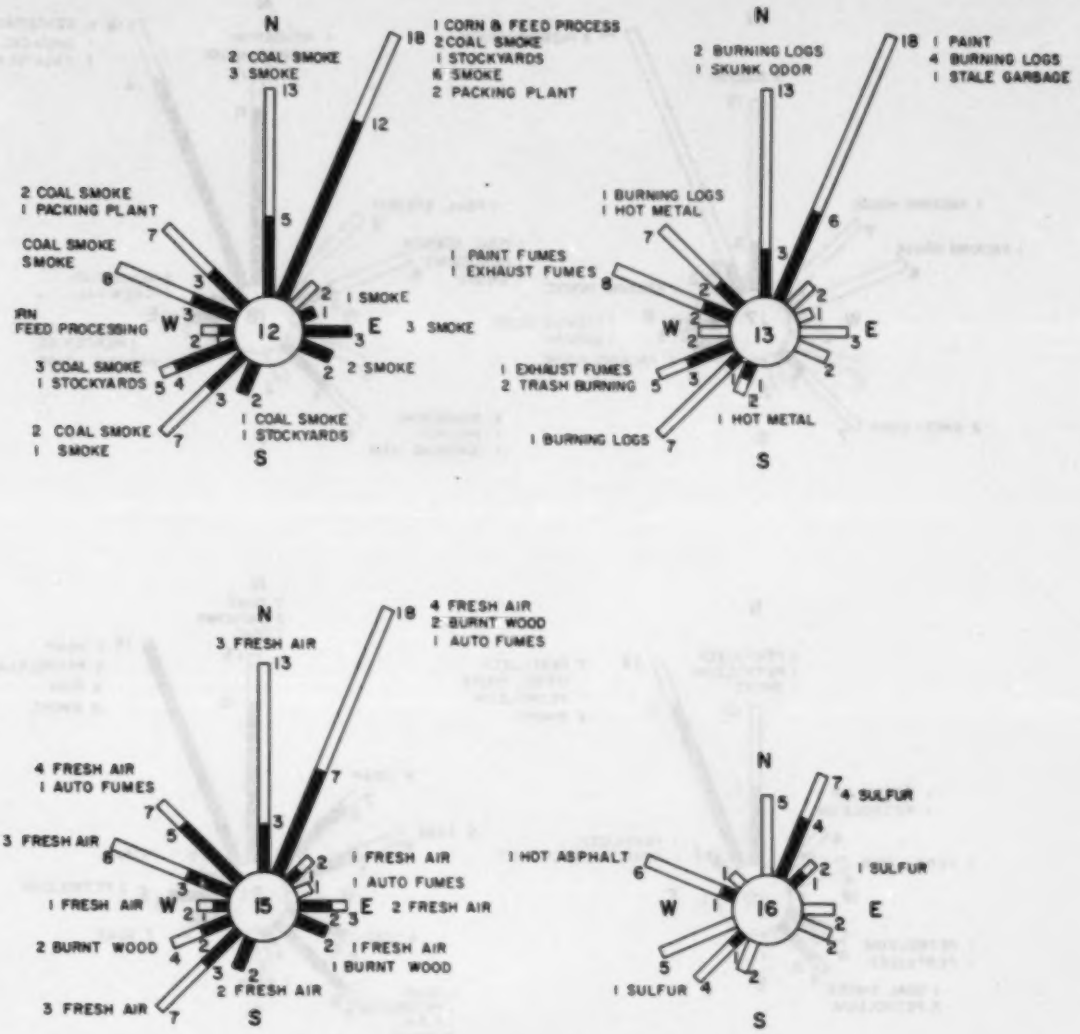

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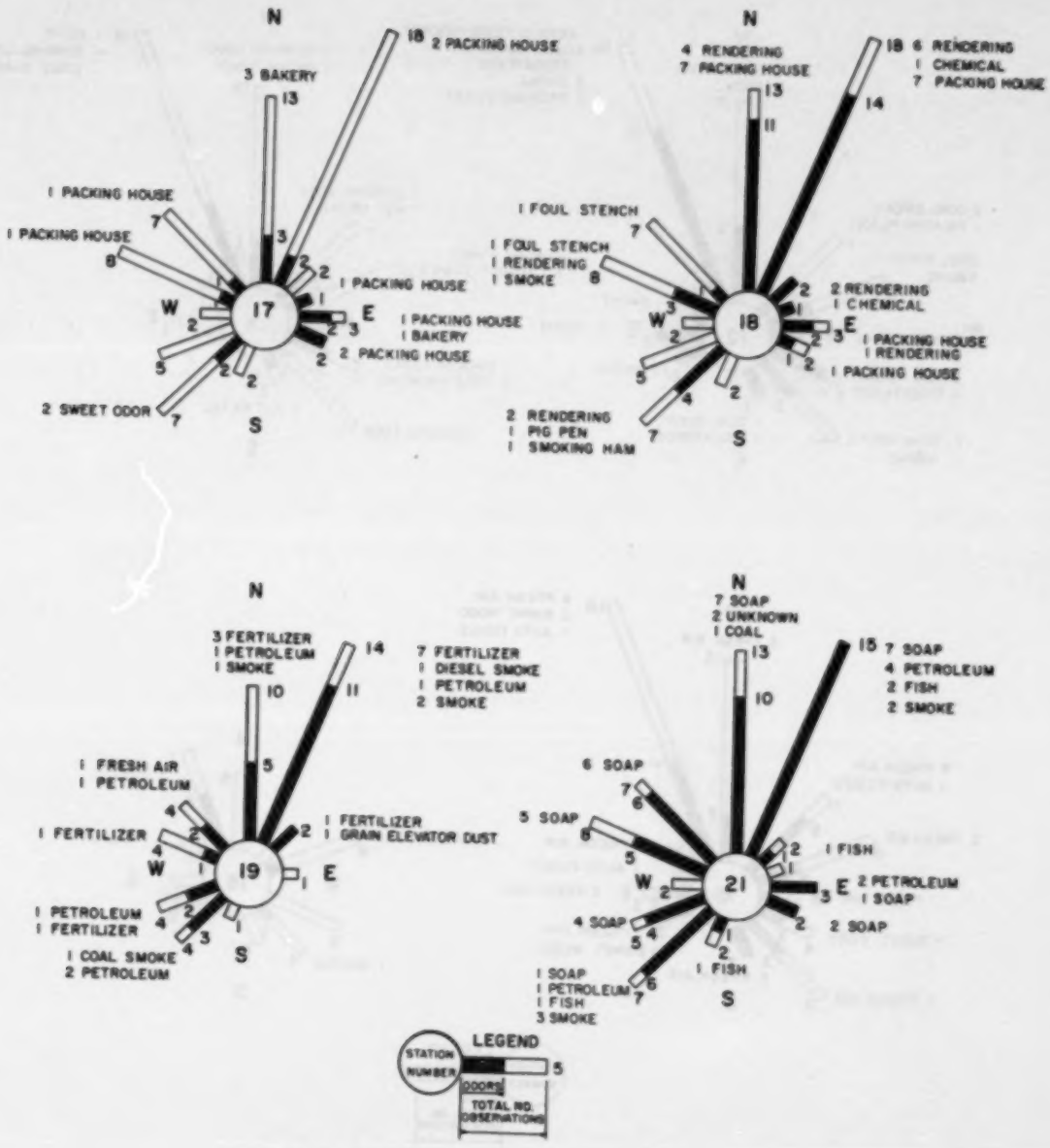

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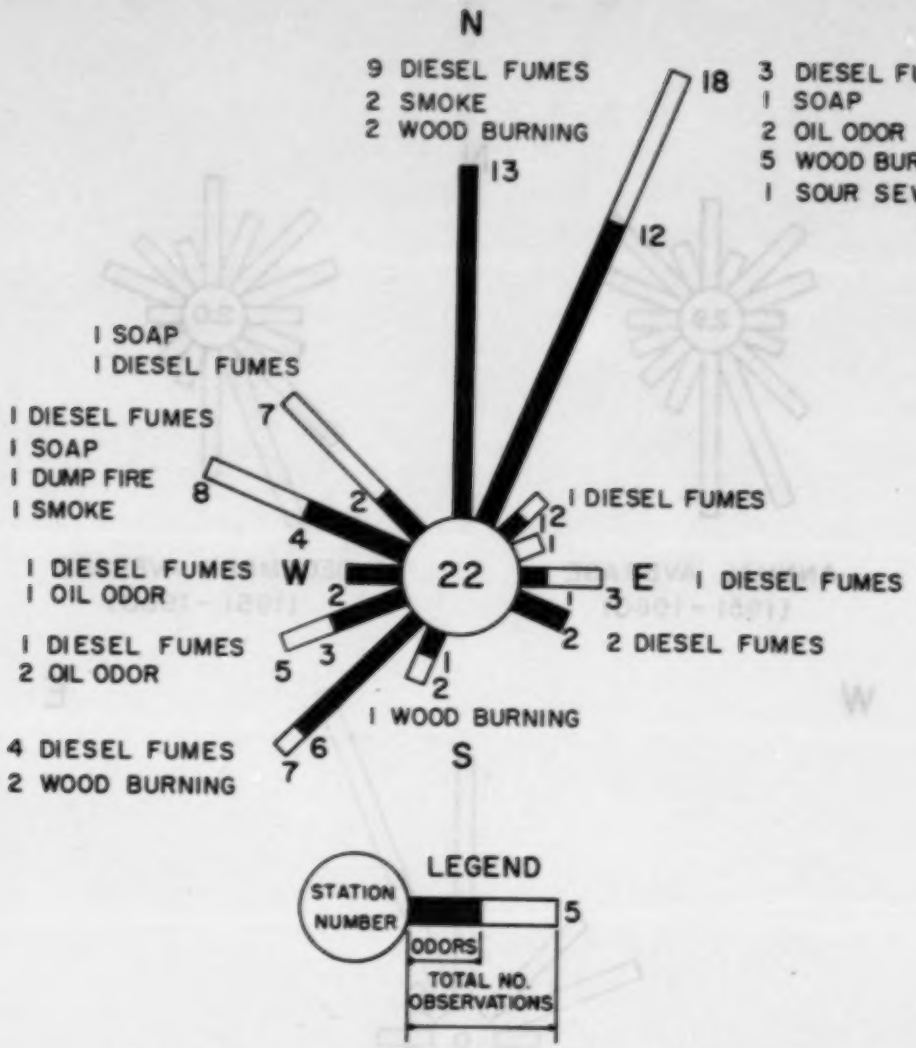

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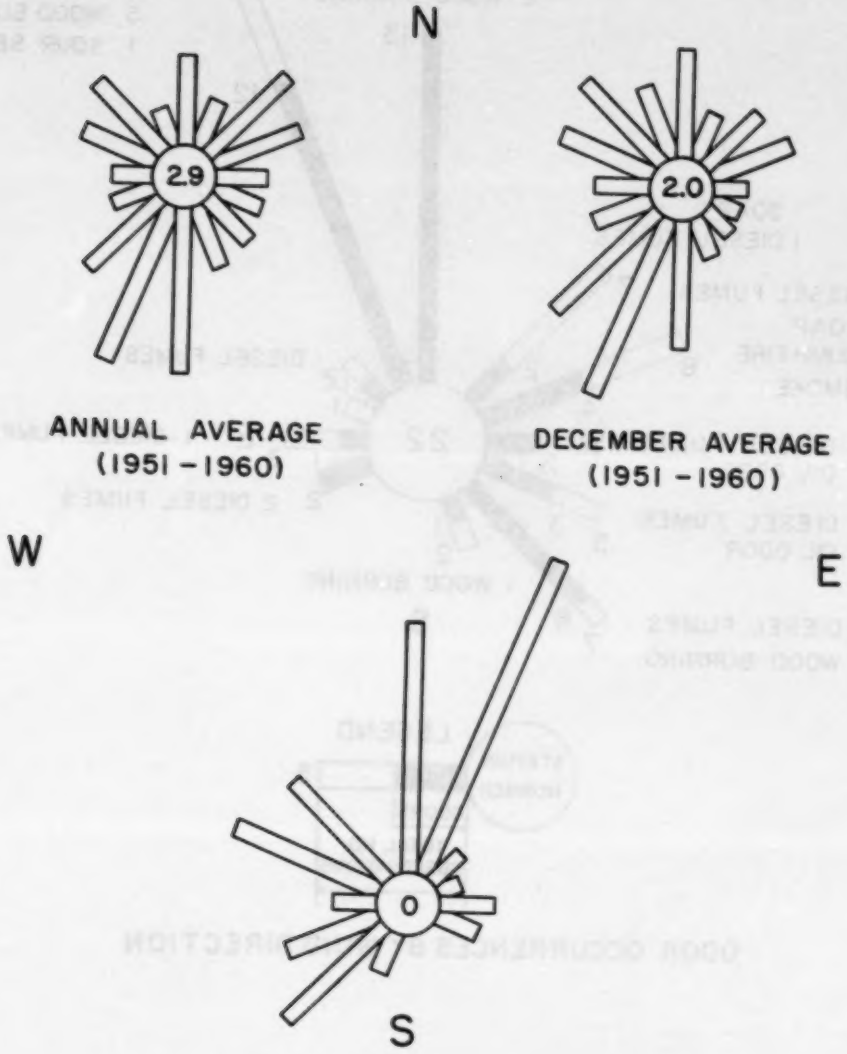

PERCENTAGE FRQUENCIES OF WIND DIRECTION

KANSAS CITY MUNICIPAL AIRPORT

A-6

METEOROLOGICAL DATA FROM
MUNICIPAL AIRPORT
KANSAS CITY, MISSOURI

Date	Time	Wind speed, mph	Wind direction	Precipitation	Pasquill-Gifford-Turner stability
1963					
12/9	0700	14	NW	None	D
	1400	12	WNW	None	D
	2000	6	NE	None	E
	2200	8	NNE	None	D
	2400	9	N	None	D
12/10	0700	9	NNE	None	D
	1400	12	NE	Snow shower	D
	2000	12	NNE	Snow	D
	2200	15	NNE	Snow	D
	2400	13	NNE	Snow	D
12/11	0700	12	NNE	Snow	D
	1400	13	NW	Snow	D
	2000	12	WNW	None	D
	2200	12	NW	None	D
	2400	9	W	None	E
12/12	0700	7	SW	None	E
	1400	14	SW	None	D
	2000	9	SW	None	D
	2200	6	SW	None	F
	2400	6	WSW	None	F
12/13	0700	10	WNW	None	E
	1400	14	WNW	None	D
	2000	10	WNW	None	E
	2200	12	WNW	None	D
	2400	14	WNW	None	D
12/14	0700	10	WSW	None	E
	1400	8	WSW	None	C
	2000	7	WSW	None	E
	2200	8	WSW	None	E
	2400	5	NNE	None	E

METEOROLOGICAL DATA FROM
MUNICIPAL AIRPORT
KANSAS CITY, MISSOURI (CONT.)

Date	Time	Wind speed mph	Wind direction	Precipitation	Pasquill-Gifford-Turner stability
12/15	0700	7	N	Snow shower	D
	1400	6	N	None	C
	2000	8	N	None	D
	2200	7	N	None	E
	2400	5	NNE	None	F
12/16	0700	7	ENE	Snow	D
	1400	7	E	Snow	D
	2000	6	ESE	None	D
	2200	10	ESE	None	D
	2400	7	E	None	D
12/17	0700	8	SSW	None	D
	1400	12	NW	Snow	D
	2000	14	WNW	Snow	D
	2200	21	NW	None	D
	2400	17	NW	None	D
12/18	0700	10	NW	None	E
	1400	7	W	None	C
	2000	6	SW	None	F
	2200	7	SW	None	E
	2400	8	SSW	None	E
12/19	0700	10	SW	None	E
	1400	10	NNE	None	D
	2000	13	NNE	None	D
	2200	9	NNE	None	E
	2400	9	NNE	None	E
12/20	0700	10	NNE	None	D
	1400	12	N	None	D
	2000	8	E	None	E
	2200	9	N	None	D
	2400	9	NNE	None	D
12/21	0700	5	NNE	None	F
	1400	10	N	None	D
	2000	10	NNE	None	E
	2200	9	NNE	None	D
	2400	8	NNE	None	E
12/22	0700	8	N	None	E
	1400	9	N	None	C
	2000	8	N	None	E
	2200	8	N	None	E
	2400	6	N	None	F

PASQUILL-GIFFORD-TURNER

KEY TO STABILITY CATEGORIES

Surface wind speed (at 10 m), mph	Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or > 5/10 Low cloud	< 4/10 Cloud
< 4.5	A	A-B	B	-	-
4.5-6.7	A-B	B	C	E	F
6.7-11.2	B	B-C	C	C	E
11.2-13.4	C	C-D	D	D	D
13.4	C	D	D	D	D

Definition of Stability Letters

A Extremely unstable
B Unstable
C Slightly unstable
D Neutral
E Stable
F Very stable

The above table gives the six classes of stability in terms of the surface wind, the solar insolation for the daytime, and the cloud cover at night. Strong insolation corresponds to a solar altitude greater than 60° with clear skies, and slight insolation corresponds to a solar altitude from 15° to 35° with clear skies. Cloudiness, which decreases insolation, was considered along with solar altitude in determining insolation. Insolation that would be strong with clear skies was classified as moderate with broken middle clouds and as slight with broken low clouds. The neutral category, "D," was assumed for conditions with cloud cover greater than 6/10 and a ceiling less than or equal to 10,000 ft. during day or night.